Military Operations Research Society

Command, Control, Communications, Intelligence, Electronic Warfare Measures of Effectiveness (C^3IEW MOE) Workshop

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Vernon M. Bettencourt, Jr—General Chair

Final Report

Edited by LTC Thomas J. Pawlowski III

Contributors:
Mr. James B. Duff
Lt Col Kenneth C. Konwin
Mr. Donald W. Kroening
Dr. Michael G. Sovereign
Dr. Stuart H. Starr

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Conducted at Fort Leavenworth, Kansas

20-23 October 1992

101 South Whiting Street • Suite 202 • Alexandria, VA 22304-3483 • (703)-751-7290 • FAX: (703)-751-8171
e-mail: rwiles@dgis.dtic.dla.mil

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Chapter I

Introduction

1.0 Purpose

The requirement to measure the effects of C³IEW systems on battle outcome continues to challenge the operations research community. This community has long recognized the difficulty in measuring C³IEW system effectiveness in terms of battlefield attrition and end strengths. However, with the recent political changes in the world, the changing role of US military to a power projection force, and the lessons of Desert Storm, the need to analyze and understand the effects of C³IEW systems has never been greater. The doctrinal evolution of military operations has heightened the need for campaign level C³IEW measures of effectiveness (MOE).

The purpose of this report is to document the results of a MORS sponsored workshop held at Fort Leavenworth, Kansas, in October 1992 to address the development and application of C³IEW MOE throughout DoD.

1.1 Background

Research efforts directed at the development and application of C³IEW measures of effectiveness have experienced periodic surges in interest and activity followed by relatively dormant periods. For example, within the U.S. Army, the period from the mid- to late-1970s saw development of new automated command and control systems, such as the Tactical Fire Direction System (TACFIRE) and the Tactical Operations System (TOS). These systems were being developed with all haste and they held great promise for increasing force effectiveness. Along with these developments, of course, came the requirements for operational test and evaluation and for the conduct of Cost and Operational Effectiveness Analysis (COEA). This led to a flurry of activity to develop C³IEW measures of effectiveness Unfortunately, the tests and the COEAs failed to show an increase in effectiveness which could be attributed to these systems. This was due, in part, to the inability to measure the effectiveness of these systems either in the tests or in the combat models used in the COEAs.

This inability to measure effectiveness contributed significantly not only to the cancellation of the TOS program by Congress, but also to a marked decline in the Army's efforts to develop C³IEW measures of effectiveness.

By 1985 the rapid growth of computer technology had greatly expanded the capabilities of automated C³IEW systems. Command and control systems became larger, more automated, and more integrated with communications, intelligence, and electronic warfare systems. In light of these developments, there was a renewed interest in the development of a practical set of measures of effectiveness and evaluation methodologies to support military decision makers throughout the DoD in their assessments of command and control and C³IEW systems. Recognizing this need, MORS sponsored a C^2 Evaluation Workshop in January 1985 to develop a conceptual model for C^2 and

provide an analysis framework for measuring the performance and effectiveness of C^2 systems within that model. This framework was called the Modular Command and Control Evaluation Structure (MCES). The product of the workshop was a draft report which was subsequently finalized and published by MORS in June 1986. Also in 1986, the application of MCES to a series of military C^3IEW systems was demonstrated and results published by the Naval Postgraduate School in September 1986. From this point through 1991 few new developments of C^3IEW measure of effectiveness are documented.

In November of 1911, the US Army TRADOC Analysis Command (TRAC), at the direction and under the sponsorship of Mr. Walt Hollis, Deputy Under Secretary of the Army for Operations Research [DUSA(OR)], conducted a C^3I Modeling and Simulation Conference. The purpose of this conference was to share what C^3I activity was in progress in the Army training, testing, analysis, and research communities and to determine what needed to be done to collectively improve these activities. One major recommendation from this conference was that more work was needed in C^3I measures of effectiveness development and that this work needed to result in more consistent measures across these communities. As a result of this conference recommendation, Mr Hollis, as a MORS sponsor, asked MORS officials to consider sponsoring a workshop to address C^3IEW MOE development. TRAC volunteered to host this workshop for MORS at Fort Leavenworth. The workshop was conducted from 20 through 23 October 1992 and was attended by some one hundred trainers, testers, analysts, and researchers from throughout DoD and the civilian community.

1.2 Workshop Organization

The attendees were divided into four working groups which reflected the functional areas of the military OR community: Operations, Plans, Training; Analysis; Test and Evaluation; and Research. Additionally, a synthesis group participated in the discussions with all working groups. The synthesis group had a member in each working group to identify common threads among the groups and to summarize the main points of the discussions.

The workshop began the evening of 20 Oct 92 with a dinner and an address by COL Jim McDonough, Director of the School of Advanced Military Studies, USACGSC. COL McDonough discussed the concept of a campaign and provided some insights on the changes being made to the Army's doctrine. The intention of his discussion was to focus the group on relating MOP, MOE and MOFE to the theater campaign level. Appendix A provides excerpts from this presentation.

The workshop ran as a series of four working sessions, with each session discussing one of the four objectives. Each session began with an address by an invited speaker. After each address, the participants divided into their working groups to address the appropriate objective. At the end of the working session, the participants assembled to hear each Working Group Chair report on the findings of their working group.

The keynote address, which also acted as the address for the first session, was presented by LTG Wilson A. Shoffner, Commander, USA Combined Arms Command. General Shoffner shared his views on command and control, and the effect of recent world changes on the conduct of campaigns.

General Shoffner provided a superb discussion of the dynamics of the future battlefield, the role of battle command in a campaign, and the relationship between command and control. He emphasized that command and control are not one word. Command is an art that is the commander's business, while control is a science that is the staff's business. A key issue that he raised was to give up on modeling the intuitive aspect of the decision making process and use a man-in-the-loop to represent the decision maker. Appendix B contains excerpts from LTG Shoffner's presentation.

The other plenary presentations were made by Dr. Mike Sovereign, Dr. Hank Dubin, and Mr. Ed Brady. Dr. Sovereign reviewed MCES, which was developed during the 1985 MORS Workshop. He used the VTOL UAV as n example to show how to implement MCES on a real system.Excerpts from his presentation are located in appendix C. Dr. Dubin addressed the definitional context of C^3I measures, typical measures, teaching command and control, and the challenges associated with this field. Highlights of his presentation are in appendix D. Mr. Brady's address provided an historical perspective with the key trends and key issues, and presented some thoughts on emerging tools and technologies. Excerpts are in appendix E.

1.3 Workshop Objectives

There were four objectives for the workshop. Each working group was asked to address the questions associated with these objectives. The objectives and questions are listed in the Table I-1 below:

Table I-1. Workshop Objectives

Objective 1:	Definition of Force-level C^3IEW
	• What is the nature of force-level C^3IEW within a Campaign?
	• What are terminology differences among services?
	• What are key essential elements of analysis (EEA) associated with force-level C^3IEW?
Objective 2:	Description of Force-level C^3IEW Measures
	• What are C^3IEW MOP, MOE and MOFE and the relationship among them?
	• What are the differences in perspective between testers, trainers, analysts, researchers and developers?
	• What approaches/methodologies can be used to develop these measures?
Objective 3:	Quantifying C^3IEW Measures and Answering C^3IEW EEA
	• What Capability currently exists to collect and quantify C^3IEW measures?
	• What are the problems associated with this capability and how can they be overcome?
	• How can testers, trainers, analysts, researchers and developers best work together?
Objective 4:	Tools and Methodologies to support C^3IEW Evaluation
	• What deficiencies exist in the tools and methodologies used to measure C^3IEW?
	• How can emerging technology overcome these deficiencies?
	• How can we work together to improve our tools and methodologies?

Chapter II

Definition of Force-level C³IEW

2.0 Introduction

To proceed through the process of describing force-level C³IEW measures of effectiveness, it is important to first define what is meant by a campaign and force-level C³IEW. The working groups identified numerous descriptions from a multitude of perspectives. One description for a campaign from the draft Joint Pub 5-00.1 says that "campaigns represent the art of linking battles and engagements in an operational design to accomplish strategic objectives..." In this context a campaign can then be defined as "a series of related military operations aimed to strategic objectives within a given time and space."

With the role of the military focusing more on operations other than war, i.e., peacekeeping activities, relief activities such as Operation Provide Comfort, and the relief effort in Somalia, the characteristics of a campaign may change and likewise change the nature of C³IEW within a campaign. As noted in COL McDonough's dinner speech (see appendix A), the Army is rewriting its doctrine to incorporate the entire spectrum of military operations, from peacekeeping activities to total war. Any effort in describing C³IEW measures of effectiveness must ultimately account for the variety of missions that can be undertaken by the military in a post-Cold War environment. However, for purposes of narrowing the scope, this workshop focused on combat operations with forces already in-theater.

2.1 The Role of C³IEW in a Campaign

A campaign provides a framework for discussing force-level C³IEW. Today, any campaign conducted by U.S. military forces must be considered a joint campaign run by a CINC or Joint Task Force Commander. Single service campaigns are not a reality any more. In terms of unit size, force-level implies corps or echelons above corps (EAC) for Army, numbered Air Force, and Battle Group or Battle Force for the Navy.

Joint Pub 1-02 defines command and control as ". . . the exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of a mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission." This definition is invariably included at the beginning of any document discussing command and control. This report will be no different in that sense. What is important from this definition is the understanding of the role command and control systems in supporting the commander to accomplish these functions.

From *Control of the Joint Force: A New Perspective*, "General Depuy reminds us that the purpose of command and control is to produce unity of effort from a diversity of means and that the key ingredient is not the automated systems, but the mind of the

commander." The focus of command and control, and all of C³IEW, must be to better support the friendly commander's decision making process and to degrade that of the opposing commander. To make the best decision, the commander must have the best information available. It is the role of the C³IEW to provide that relevant information in a timely, accurate manner.

In his keynote address (Appendix B), LTG Shoffner described the nature of the future battlefield as having the potential for an accelerated tempo. Lethality is increasing; mobility is increasing; weapons precision is increasing; and, range of fires is increasing. The acceleration in these battlefield dynamics brings an increase in the amount of information and intelligence that the commander must comprehend in a short period of time. The employment of multiple lethal weapons in the attack will require intricate coordination and timing that only a sophisticated command and control system can provide. Likewise, disruption of the enemy's capability could allow the commander to control or slow the op tempo when beneficial to friendly forces.

While command is primarily an art, control is primarily a science. Intelligence provides the perception of the enemy, while electronic warfare provides the means to deny the enemy an accurate perception of friendly forces. Communications provides the glue to make it all tie together. C³IEW as a whole provides the grease to reduce the friction of war, across concept formulation, planning, and execution.

2.2 Differences in Terminology

One of the hurdles that must be overcome in the effort of describing C³IEW and C³IEW measures is the difference in terminology among the services and the tremendous number of acronyms. There are real differences in C^2 systems among the services as well as different Intelligence and EW systems, so terminology can not be expected to be the same. Message text formats and data dictionaries are becoming standardized but procedures are still unique, often to specific commands and commanders. This affects the problem of interoperability in both the real and the modeling worlds.

No adequate joint theater-level campaign C³IEW model exists although PACOM may be beginning to build one. Joint exercise support systems are being cobbled together: Aggregate Level Simulation Protocol (ALSP) and Data Bus, for example, are linkages of major war games that could be used to examine C³IEW.

2.3 Essential Elements of Analysis

Not only are there differences among the services in terminology of C³IEW systems, there are also differences among the services in analysis terminology. The term, Essential Elements of Analysis (EEA), is not often used outside of the Army. One suggested term is 'critical analysis questions' as an equivalent, but there is difficulty even in defining those. One question which recurs is whether EEA are exclusively developed to support analysis for acquisition or for operations, training, etc. Army EEA seem to be designed for use across acquisition of all types of systems. For C³IEW analysis, the proposed essential elements of analysis are summarized in Table II-1. These emphasize the key decisions that are made in the campaign and the information required to support the decisions. Unfortunately, there is no reference document for the campaign decisions!

Table II-1. Essential Elements of Analysis for C^3IEW

• What is the applicability of information at each echelon? How does a system get the right data/information to the right person at the right time?
• What are system classification issues that need to be overcome to complete analysis?
• What does a C^3IEW system need to do and how well does it need to do it?
• What are the key decisions that affect the campaign outcome?
• Does the proposed change/system/process support the commander's needs?
• What are the key information elements needed by the joint component commanders and their staffs?
• When is information needed?
• Does missing, late or inaccurate information change key decisions?

The view of C^3IEW EEA shown in Table 2-1 suggests that the C^3IEW process is a hierarchy with command at the top, control in the middle, and communications tying sensors to information, intelligence, and EW systems at the bottom. With this structure, some EW functions, such as jammers and radar warning receivers on aircraft, reside outside of a force-level discussion.

An important question that remains unanswered is: at what level of resolution should the decisions be represented in an analysis of force-level C^3IEW? No concurrence was reached with some believing that an aggregate level was adequate, while others believed that much more detailed modeling would be needed, for example that logistics decisions would be necessary.

Chapter III

Description of Force-level C³IEW Measures

3.0 Introduction

The MORS workshop on C² MOE in 1985 laid the foundation for much of the content of this chapter. One of the results of that workshop was the Modular C² Evaluation Structure (MCES), a methodology to identify measures that are appropriate for C² analysis. The MCES approach was described in a plenary presentation by Dr. Mike Sovereign. His presentation is summarized in Appendix C. Key elements of the work from the 1985 workshop include a set of definitions for measures and the establishment of a relationship among those measures. This relationship provides the framework in which an analysis of a C² system can occur.

3.1 Definitions

The 1985 workshop provided the initial set of definitions for C² measures. Ingram and Short modified these definitions slightly in their 1991 paper, *Command and Control Measures: A Proposed Approach*. These definitions are modified and extended to apply to C³IEW systems:

C³IEW system. A C³IEW system has three components: physical entities, structures, and processes.

(1) *Physical entities* refer to equipment, software, facilities, and people.

(2) *Structures* identify the arrangement and interrelationships of physical entities, procedures, protocols, concepts of operation, and information patterns. Such arrangements are often spatial and temporal.

(3) *Processes* are what the system is doing and reflect the functions carried out by the system.

Dimensional parameter. A property or characteristic inherent in the physical entities whose value determines system behavior and the structure under question even when at rest. Examples are size, weight, capacity, and number of pixels. These measures are obviously scenario independent.

C³IEW measure of performance (C³IEW MOP). A measure of an attribute of system behavior. Examples are throughput and error rate. C³IEW MOP are related to the inherent parameters (physical and structural), are internal to the system being analyzed, and are scenario-independent.

C³IEW measure of effectiveness (C³IEW MOE). A measure of how a C³IEW system affects the other entities within an operational environment. Examples are reaction time, number of targets detected, and susceptibility to deception). C³IEW MOE are measured relative to some standard or baseline, which is often implicit (e.g., how a perfect C² system would perform). C³IEW MOE are scenario-dependent.

Measure of force effectiveness (MOFE). A measure of how the force performs its mission. These are typically measures that are used for weapon system analysis, for example, loss exchange ratios (LERs), or

number of weapons destroyed. As with C^3IEW MOE, MOFE are scenario-dependent.

Boundary of a C^3IEW system. The delineation between the C^3IEW system being studied and the environment. Within this definition, measures can shift from one type to another depending on the context of the C^3IEW system boundary. Figure III-1 graphically shows the relationship of the measures defined above. This diagram is typically referred to as the 'onion' diagram, because each layer can be pealed back to reveal the next lower level.

3.2 Measure Relationships

NOTE: For purposes of generalization, the term, Measures of Merit (MoMs), will be used to refer to all measures.

There are several ways to view C^3IEW Measures of Merit and their relationship. Each viewpoint provides a different perspective toward the measures. Three viewpoints are presented here: the 'onion' diagram, the hierarchical relationship, and the properties measures.

The 'onion' diagram of the MCES can be used as a tool for bounding the problem. But, the boundaries of the system must be drawn carefully for the definitions to work. That must be accomplished within the context of a particular analysis to answer the EEA. The perspective from which the analysis occurs may change a measure of effectiveness to a measure of performance. For example, depending on the level of the analysis to be examined, measures which are normally MOEs for lower level examina-

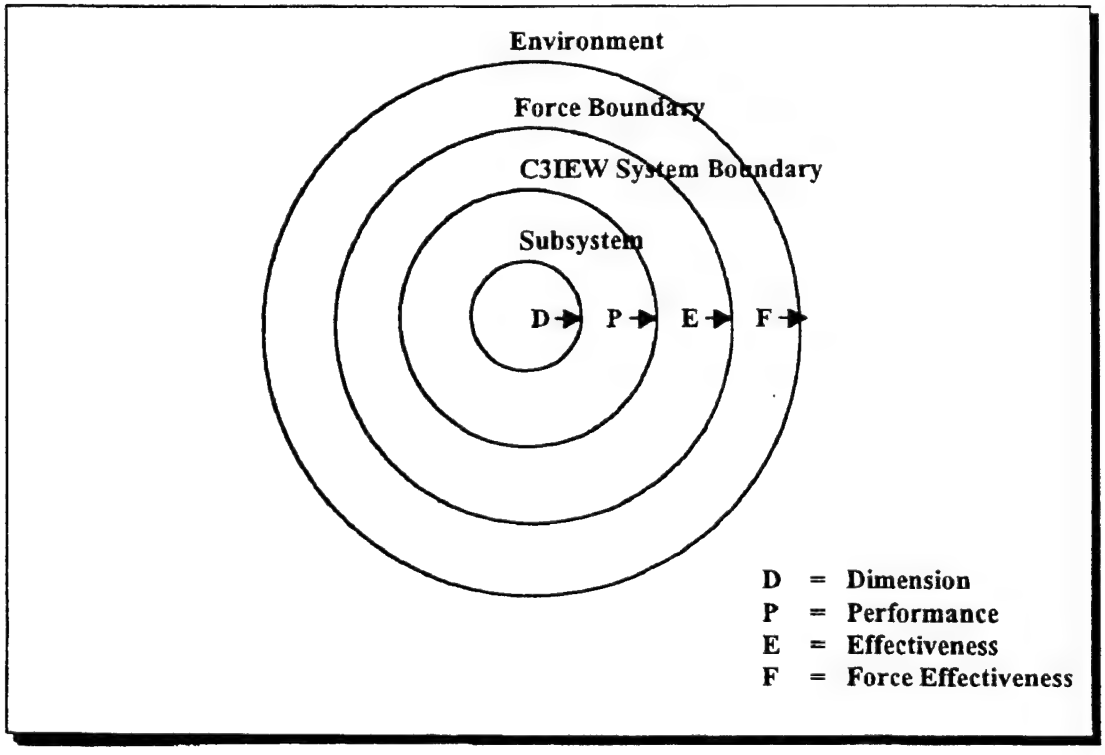

Figure III-1. 'Onion Diagram'

tions may become assumptions at higher levels.

The hierarchical relationship of measures of merit suggests an ordered structure that allows the linking of lower level measures to higher level measures. In this relationship, measures of effectiveness (MOE) can be linked to certain measures of performance (MOP) which, in turn, can be linked to specific dimensional parameters (DP). To use this relationship effectively, the lower measures can be analyzed to provide some indication of the higher level measures. If a direct relationship can be established between lower and higher measures, conclusions can be reached about system effectiveness through the analysis of system performance. Care must be taken to appropriately extend a cause and effect relationship to this hierarchical structure. Figure III-2 depicts the hierarchical relationship for both weapon systems and C^{3}IEW systems.

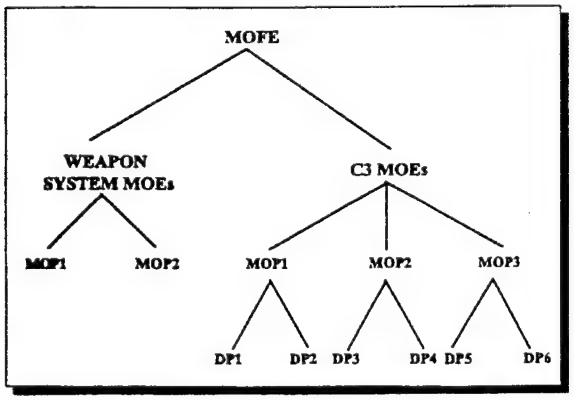

Figure III-2. Hierarchical Relationship of Measures

Measures can be described in terms of the level of resolution of a particular property of the C^{3}IEW system. This approach dissects a system in terms of its functionality or purpose and the properties associated with that functionality. Through this description, measures of merit can be developed and associated with the key properties of the system. Table III-1 provides an example of the levels of a system property. Although the term 'MOE' is used in an analysis, it is often unclear which property level is being considered.

Table III-1. Levels of a System Property

PROPERTY	EXAMPLE
1. Family Name	Vulnerability
2. Surname	Susceptibility to Jamming
3. System Reference	VAV Data Link
4. Functional Ref.	Sense
5. Units	BITS/Sec
6. Value	1000
7. Threshold	1

3.3Differences in Perspectives of Measures

There are clearly differences in the perspective of the researchers, analysts, testers and trainers. This is due in part to the differences in disciplines, but it can also be attributed to the different stages of acquisition in which communities interact with the C^{3}IEW system. Researchers typically function in the long term, developing several new technologies for later application in a system. Developers are in the mid to long term in developing requirements of a few potential systems. Testers perform their evaluations of one or two systems in the near to mid term as a system reaches its later milestones prior to fielding. Trainers operate with one system in the near term when the fielding commences. Analysts operate across the entire range working with researchers to implement new technologies in analytic models, supporting the developer by analyzing sever-

al concepts, supporting the acquisition process in general with COEAs and weapon system versus C^3I system tradeoff analyses.

The difference in time horizon and the separation of the communities make it difficult to coordinate the development of measures. However, it is not clear that this must be done except for neatness. The EEA are not necessarily the same for each community. That is not to say that it would not be valuable for each community to pay attention to what measures are used by the others. With the trend toward compressing these timelines, the need for cooperation among the communities appears to be growing.

There are three points that summarize the concerns of the workshop:

- The COEA process is putting pressure on early identification of measures and linkage of analysis measures to testing measures.

- Measures for COEAs must enable tradeoffs to be made between C^3IEW systems and weapon systems, as a matter of policy. In other words, MOFE are necessary. But MOFE are inherently less discriminating than MOEs or MOPs.

- Existing C^3 and force-level models should be used to avoid the necessity of building new, unique data bases. (This point was contested later by the sponsors of the meeting who assured participants that resources would be made available for the necessary new models and data.)

3.4 Methodologies for Deriving Measures

The most familiar methodology in the MORS community is the MCES. It is based on the scientific method and the cybernetic loop model of C^3. Although implementation is not complete, it is difficult to attack as unsound.

A more mathematically rigorous methodology, an offshoot of the MCES, has been developed by Paul Girard, one of the MCES originators. The latest version of this approach introduces an expected utility framework to deal with decision-making. It has not yet been applied to a real problem because of implementation difficulties.

Another offshoot of MCES has been proposed by several TRAC analysts. A read-ahead paper by Mr Mike Ingram and Captain Robert Short proposed a functional breakout based on the Army's doctrine as described in FM 100-5. Their methodology, called Structured Resolution Approach, describes three levels for analysis of command and control systems. A mission level examines measures that determine if a force was able to accomplish its mission. This level generally focuses on command and control measures of effectiveness. An airland battle tenet level examines the ability of a C^2 system to support the four tenets (agility, depth, initiative, synchronization). This level focuses on command and control measures of effectiveness. Finally an imperative level focuses on the ability of a C^2 system to contribute to implementing the imperatives of AirLand Battle doctrine (unity of effort, anticipation, concentration, main effort, press the fight, move fast, use terrain, conserve forces, joint and combined arms, morale). This level relates to the MOE/MOP for C^2 systems. The Structured Resolution Approach shows promise for Army C^3IEW analysis, but may not apply to other services.

This approach has recently been modified to examine C³IEW systems in terms of their contributions to the battle. Under this modification, C³IEW systems are examined to determine their ability to contribute in various areas where a C³IEW system is expected to enhance the commander's execution of the battle. Within each area of contribution, measures are identified which describe the amount of contribution being made by the C³IEW system. Example areas of contribution are shown in Table III-2.

Another methodology briefly discussed was the Headquarters Effectiveness Tool (HEAT) which is now in use in the Army as a part of the Army Command and Control Evaluation system (ACCES) for exercise evaluation. ACCES has a cybernetic loop like the functional process loop in Module 3 of the MCES. It has an overall MOE of 'life of the plan' and a set of MOE/MOPs at each stop in the cycle. They compare observable performance with the standards derived from standard operating procedures (SOPs). HEAT has a proven data collection scheme for headquarters processes in field exercises or experiments.

A final methodology is the new framework for C^3 within the Combat Science definitions devised by a group of prominent analysts. The C^3 definitions have been suggested by Professor Wayne Hughes in his paper *C^3 in a Theory of Combat Science* (NPS Technical Report No. 55-89-05). This paper draws heavily on the MCES and HEAT methodologies, but is consistent with the broader scope of Combat Science.

Of the methodologies, to date, the review of literature and analysts' experience suggests that the MCES had the widest support as the broadest, most applicable (but incomplete) methodology.

Table III-2. Areas of Contribution for a C³IEW System

- Develop situation awareness
- Provide a common picture of the battlefield
- Facilitate control of battle tempo
- Reduce shooter to shooter timeline
- Filter information
- Allow anticipatory actions
- Enhance commander's agility
- Support synchronization of the battle
- Support commander's initiative
- Provide near real-time intelligence

Chapter IV

Quantifying C^3IEW Measures

4.0 Current Capabilities

There are three current efforts within the Army to produce quantification of C^3IEW measures. The first is the Command and Control Functional Area Model (C^2FAM) effort to support the TRAC command and control studies. It incorporates a Model-Test-Model approach and relies on exercises and subject matter expert (SME) panels for C^2 input data. SME panels use a structured Delphi technique to capture data.

The C^2FAM approach uses command and control performance models linked to force effectiveness models to determine the effectiveness of a C^2 system. The performance models are Petri net representations of information flow within the C^2 structure. The goal of this modeling effort is to represent all battlefield functional areas (BFA) from theater to brigade level. The BFAs include maneuver, fire support, intelligence, air defense and combat service support. These performance models are then linked to an appropriate force effectiveness model such as Vector-in-Commander (VIC), Eagle, or TACWAR. This linkage provides the key to demonstrating the combat effectiveness of the C^2 system. By using the output from the performance models as input to the force effectiveness models, the C^2 system's impact on battle outcome can be determined. This methodology allows the conduct of a performance analysis as well as an effectiveness analysis for the C^2 system. Figure IV-1 provides a graphical representation of the C^2FAM methodology.

As seen in the figure, the methodology incorporates a modeling tool called Modeler to develop the C^2 performance models. Modeler allows the rapid creation of Petri

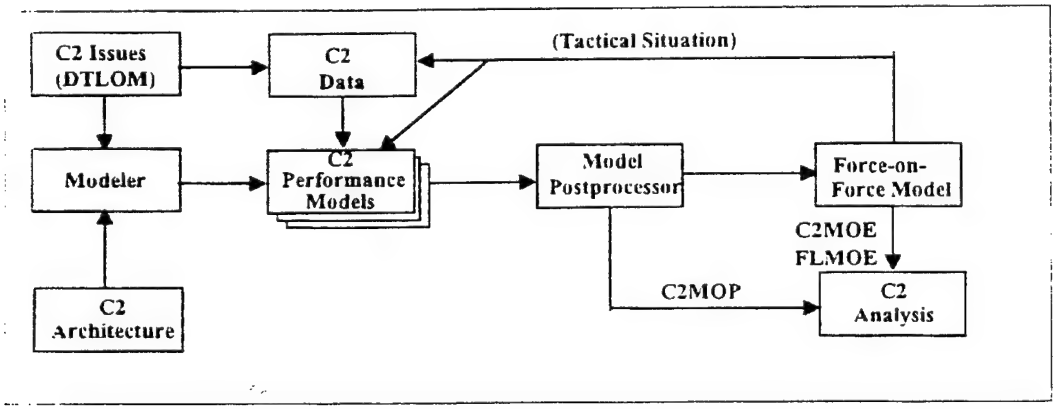

Figure IV-1. C^2FAM Methodology

Table IV-1. OPVIEW Methodology

OPVIEW

(Operational Value of Intelligence and Electronic Warfare)

- OPVIEW focuses on MOEs for Intelligence (and EW somewhat) as they relate to the command and control decision process.
- More specifically, the emphasis is on mission accomplishment, support of the plan and monitoring the plan through PIRs (prioritized intelligence requirements).
- The methodology is based on PIRs.
- Any PIR can be classified as a combination of eight functions:
  - Detect
  - Locate Generally
  - Locate Precisely
  - Classify
  - Identify
  - Trade
  - Acquire
  - BDA (assess remaining operational capability)
  - Intelligence collection assets attempt to meet PIRs.
  - Meeting (or failing to meet) PIRs in a timely manner provides a perception to the command element.
  - The perception provides information to the plan status/accomplishment.
  - Plan status affects the decision process.
  - The decisions affect the forces.
  - Orders to the forces affect the battle outcome.
- EW supports these eight PIR functions, and counters the enemy's ability to support his own eight PIR functions.
- This methodology has been applied to noncombat as well as combat missions.
- The methodology has been applied in three model applications.

nets to represent the information processing in a command and control structure. Modeler was developed by Alphatech, Inc. for the Air Force, but it is now being used by numerous military and civilian organizations.

The second approach is employed at the ATCCS Experiment Site (AES) located at Fort Lewis, Washington. In this approach the activities of the 9th Infantry Division (ID) headquarters have been extensively recorded and analyzed in field exercises. In this effort there are a number of headquarters tents and shelters which are instrumented with TV-recorders. Additionally, a data capturing system taps into all data bases in the headquarters. This effort has developed a cadre of experienced analysts with an understanding of the process flow within a command post. Unfortunately, the 9th ID has been deactivated, but part of the 7th ID will move to Fort Lewis and the AES will probably continue.

A third effort is the RAND Operational Value of Intelligence and Electronic Warfare (OPVIEW) methodology. This process is now in development as three related models which are based on the human translation of Prioritized Intelligence Requirements (PIRs) into intelligence taskings. The results of collection activities are displayed in a series of simple plots. Table IV-1 describes the approach in some detail. It is an aggregate-level approach which may not have sufficient detail to represent C^3IEW.

4.1 Problems with Current Capabilities

The existing capabilities have several major problems. In developing a capability to measure C^3IEW, it is difficult to identify and structure the decisions involved in or impacting on force-level campaigns. The scope and amount of detail required in the various headquarters areas (intelligence, operations, logistics, and EW in addition to other supporting services) is not clear. There is no complete doctrinal set of the decisions at the joint level. As LTC Shoffner said in his presentation (see page 31), the US approach to command is more parallel and intuitive than the Soviet cybernetic model. Service SOPs focus on procedures for planning rather than control decisions.

Modeling of information flows to support decisions is weak. C^3 is often modeled by message traffic or message size (bytes) alone. While this type of modeling is good for communications capacity analysis, this approach cannot measure the content of the messages nor directly determine changes on the basis of the information. The information requirements of some decisions are not easily established, in particular, the more creative command decisions.

There is a poor match of data required within our models. Values for performance characteristics that are required for direct measurement or in models to produce effectiveness measures are very hard to obtain under the conditions in which they are collected/evaluated.

There is a limited capability to collect and quantify C^3IEW measures at the campaign level. Collection opportunities are limited simply because of the number of exercises that involve the campaign level. When exercises are conducted, there ia an inherent difficulty in seeing real C^3IEW, because the exercises tend to be scripted, designed for training etc.

There are several problems associated with the data collection process. One is that there is often limited access to tests and exercises. Units conduct tests and exercises for purposes that are often at odds with the data collection process. Then there is a common purpose, unit commanders often do not want additional 'evaluators' in the area for fear of having their units judged by another set of eyes. Even if data were to be collected, it would consist primarily of what was done with perhaps some insight as to why. It would require much more extensive inquires (and be more intrusive to exercises) to determine what potential options were considered but rejected.

Data collection is currently performed on an *ad hoc* basis. In most cases the collection process uses subjective methods, nominal sources and focuses on tests and exercises under some artificial conditions.

Another problem is the lack of collection resources. Other than organizations such as AES, which is formally structured to collect data, most analytic agencies must depend on

internal resources to collect C³IEW data. Data reduction would also be very manpower intensive.

4.2 Solution to Problems

There are some solutions to the problems mentioned above. First, continued automation of training and collection devices should improve the data collection capability and our understanding of what to collect. Second, there must be more top down incentives for organizations to cooperate and support a data collection effort. Finally, the communities and services need to develop common data structures for C³IEW that will meet the needs of all.

There is clearly a need for research, developer, analysis, training and testing communities to work together to resolve some of the issues related to C³IEW measures. As funding and resources become scarcer, the opportunities to conduct individual community data collection efforts will disappear. It is imperative that all communities are allowed to participate in every data collection opportunity that occurs. This means that the organizations that control a data collection opportunity must have the proper incentive to allow outside organizations from other communities to participate. Training units must have a good reason to allow additional observers into their training exercises. Interservice data collection and evaluation of same will undoubtedly open all kinds of sensitivities.

Chapter V

Tools and Methodologies for C³IEW Evaluation

5.0 Deficiencies in Tools and Methodologies

The deficiencies associated with our current tools and methodologies are significant. Our current tools are too manpower intensive. We must rely on a multitude of observer/controllers to perform the data collection for C³IEW evaluation. The nature of the command and control process limits our ability to use automated data collection for every aspect of the process.

Although we must perform C³IEW force-level analyses to show the effect of C³IEW systems on the outcome of battle, our force-on-force models that are supposed to support these analyses are limited in their explicit representation of the C^2 process. Most of these models rely on a man-in-the-loop to capture the initiative aspect of the commander and to perform the command and control process. Adding the man-in-the-loop to simulations essentially nullifies any ability to replicate a run and it normally lengthens the run time.

Scenario dependence in these simulations is very high. In most cases, the scenarios are developed for weapon system evaluation rather than C³IEW system evaluation. The result is that C³IEW systems do not get stressed during the battle and become secondary factors in determining the outcome of the battle.

Also, the technology to move from system characteristics to force-level results is very limited. We have made only limited progress in linking the performance characteristics of a C³IEW system to battle outcome. Capacity bottlenecks are often not modeled in higher level models.

The C^2 process in campaign level models may not be adequate for the entire purposes of all communities. There is a need for linkage of simplified processes in campaign models to more detailed examination in finer granularity models.

In addition, there are deficiencies due to a lack of coordination across services and agencies as well as resource constraints. If we have C³IEW interoperability problems in the real world, can we really expect our models to behave any better?

5.1 Overcoming Current Deficiencies

We should perhaps explore new theories of combat and the supporting processes, i.e., C^3 in combat science stochastic decision models. This includes applying of other methodologies, such as chaos dynamics and fuzzy logic to the C³IEW problem.

Several changes are needed to place C³IEW systems on a comparable level with weapons systems. Scenarios and models need to be developed or extended to specifically support C³IEW evaluation. Policy makers in DoD must re-examine current acquisition requirements to determine if changes are need to accommodate the different nature of C³IEW systems. There needs to be a better link between the Mission Needs Statement (MNS), Operational Re-

quirements Document (ORD), COEA, and the Test and Evaluation Master Plan (TEMP).

We should strengthen our joint efforts such as the National Training Center, National Test Bed, and Defense Modeling Simulation Office (DMSO). We need to be able to respond to pressure for standardization, verification, and validation procedures from Congress, GAO, and users. We need to explore new computer tools such as object-oriented models, simulation languages with libraries of objects, and menu-driven model building similar to the CAD/CAM process. Finally, we may need to develop new models of C^3, perhaps in the form of Petri nets, conditional possibility, and variable resolution modeling and use these as providers of data to our more traditional attrition process models.

There are several opportunities that need to be explored as sources of data to support models. These include:

1. Leavenworth training - Battle Command Training Program (BCTP) and Tactical Commander Development Course (TCDC), and senior leadership conferences with 1-4 star generals.

2. National Training Center - ARI, Monterey has permanent data (video, graphics, audio, and hard copy).

3. ATCCS Experimentation Site - AES maintains complete video documentation of HQ exercises.

4. Battle Force In-Port Training (BFIT) - Battle group level, simulation driven with HEAT data collection.

5. FLAG Air Force C^2 exercises with some linkage.

6. Wargaming at service schools.

7. Future - Embedded training in every weapon system now required. This will require a new community of officers with expertise in simulation.

5.2. Improving Our Tools and Methodologies

The working groups discussed a wide range of possibilities, but had limited success with obtaining closure, except concerning the desirability of the Model-Test-Model approach. Five recommendations are:

1. Develop a mechanism for coordination among the various communities and services.

2. We need an orchestrated set of enhanced tools to meet the C^3IEW evaluation needs. This includes:

- a means to elicit expert opinion;
- constructive, virtual models and simulations that treat C^2 explicitly;
- participation in live exercises, e.g., NTC.

3. Use the Model-Test-Model approach.

4. Develop a special proposal for addressing a specific system — a joint system is preferred.

5. We need a vehicle to disseminate our progress.

Chapter VI

Findings and Recommendations

6.0 Findings

The workshop produced several major findings. Although most of these do not address the original questions associated with the objectives, the findings do highlight the fact that there is still a long way to go to integrate the efforts of the various communities to allow them to work together to achieve mutually supporting objectives. These findings also reveal the need to revitalize the work in this field to provide a common, acceptable terminology across services and communities. The findings can be categorized into five areas: processes, measures of merit, methodologies, tools and community communications.

Processes

The modeling efforts need to focus on the C^3I processes that can adequately be represented.

The C^3I process can be decomposed into two parts: automatable and non-automatable. Automatable processes include information processing, situation development, control, communications, and concept evaluation. Non-automatable processes include concept formulation, building and updating perceptual models. We have the capability to represent automatable processes in our models, but we must currently rely on human intervention to represent and perform non-automatable processes.

The impact of EW must be considered in analyses and concepts of operations.

We saw clearly in Desert Storm the effect of EW on the success of our operation. It was a significant combat multiplier when used properly in the concept of the operation. However, for the most part, the overall, joint effect of EW on force level operations has been ignored in our force-on-force models. We need to improve our representation of EW to show its impact on shortening the planning cycle time and adding to the confusion on the battlefield as it degrades the opposing commander's situation awareness.

Measures of Merit

Note: The term Measures of Merit (MoMs) was introduced to subsume all of the measures that characterize a C^3IEW system's performance (i.e., Measures of Performance), its functional effectiveness (i.e., Measures of Effectiveness), and its impact on force effectiveness (i.e., Measures of Force Effectiveness).

Measures of Merit are defined by the level of analysis and the context in which they are measured.

The context in which we are measuring MoMs affects the way in which we define them. Depending on our perspective, a measure might be a measure of performance or a measure of effectiveness. It depends on the question being answered in the analysis.

MoMs have the attributes of a name, category, system reference (boundary), a function reference (purpose), units of measure, value measured, and threshold value (goal).

Although this might not be an exhaustive set of attributes, it is a good start in the process of defining and describing MoMs.

Additionally work is required to refine this list further.

There are some major MOEs for C^3IEW systems that should be considered in evaluating the system.

Based on our experience with C^3IEW systems in using them in a variety of situations, we can identify some major MOEs that should be considered. These include the ability to: maintain multiple views of enemy courses of action; formulate and evaluate multiple friendly courses of action; configure and reconfigure rapidly for new situations (flexibility); identify and assess 'ground truth' and infer from it; and be easy to train on and use.

Alternative C^3IEW systems manifest greater changes in MOPs than Measures of Force Effectiveness (MOFE).

We should expect that C^3IEW systems have a small effect on the overall force effectiveness. That is, it is not reasonable to say that a change in one ratio will win the war. We need to be careful and clever in the way we evaluate the effect of C^3IEW systems so that we can discriminate between the effects of a C^3I system and other factors to properly reflect the impact of a C^3I system on force effectiveness. However, traditional MOFEs at the campaign level should not be rejected as a subset of those useful in C^3IEW analyses, especially when comparing sensors and shooters.

Methodologies

There exist some promising, but incomplete methodologies to define, derive, and measure MoMs.

We care a great deal about measures, but we still need an underlying methodology to provide a logical structure for how we approach this very complex problem to gather these measures. A lot of good work has been accomplished in previous efforts on MOEs, but there is still no complete or comprehensive methodology that exists. However, persistence in linking MOPs to MOEs to MOFEs will help in this regard.

Tools

Existing force-on-force models do not contain modules that adequately represent C^2 processes.

Current force-on-force models have not been very useful for analyzing the full spectrum of C^3IEW systems, because they do not explicitly represent command and control. This limits the Model-Test-Model paradigm that is needed to integrate modeling into the test and evaluation world. Likewise, the theory of how to smartly aggregate lower level cause to aggregate level effect needs to be extended.

An orchestrated set of enhanced tools is required to meet the C^3IEW evaluation needs.

There is no one magic tool that meets our needs for evaluating C^3IEW systems. We need a set of tools that will allow us to capture every aspect of the C^3IEW process to properly analyze a system. These tools must include the means to elicit expert opinions; the means to capture C^2 activity in live exercises such as at the National Training Center (NTC); and, constructive and virtual modeling and simulation that treat C^2 explicitly.

Community Communications

Continuous interrelationships are needed among the key communities (developers, testers, trainers, and researchers).

We have learned that people in these different communities speak different lan-

guages and it is sometimes difficult to communicate the needs of one community to another. We need to work more closely together to find the common ground and make our efforts mutually supporting. This is true not only within a specific service, but across services.

Security classification barriers need to be overcome.

Historically, we have not done well in playing Sensitive Compartmented Information (SCI) systems in our models and simulations. Very few people have access to these systems and information about them. If we are to properly represent their role in the battle, we need to overcome some of the barriers that we now face.

In the context of a training exercise, training and system evaluation goals are frequently at odds with each other.

In training exercises, we have very attractive activities with large groups of people gathered together, and we are unable to take full advantage of an excellent data collection opportunity. Although system evaluators see this opportunity, those being trained naturally view the evaluators as additional burdens and hindrances to their training. It is also difficult to isolate system effects from human training effects without the benefit of multiple, independent replications.

6.1 Recommendations

Several recommendations emerged from the Workshop.

Clarify the different levels of MoMs.

More work is needed in this area to accurately define the levels of measures to be used by all communities. One possible way of accomplishing this is through case studies of real systems. Particular emphasis should be given to a system which has potential impacts across all services, e.g., JSTARS.

Assess the feasibility of existing methodologies and establish a plan to make them more credible and easier to apply.

It is clear that in this area there are no cook book solutions. We need to resist the urge to be overly mechanistic. The analysis of C^3IEW systems will require creative and innovative thought. Any approach taken should be tailored to bridge the disciplinary gaps between the operational and the technical levels. Single point solutions are inadequate for this type of analysis. Sensitivity analyses are mandatory. Documentation of these efforts should be made available throughout the DoD analysis community.

Explore the potential value of applying functional decomposition techniques to enhance C^2 evaluation.

One suggestion is to take a dendritic approach to the problem.

Encourage training activities to collaborate early in the planning process with T&E to enhance dual use.

Take early steps to incorporate C^2 evaluation requirements into DIS and WARSIM 2000.

There is an excellent opportunity to affect the usefulness of training simulations for the testing and analysis communities. We must take advantage of this to provide some input into the development of these simulations.

Continue the trend to explicitly model C^3I processes in force-on-force models.

If we are able to do this, it will lay the

foundation to do Model-Test-Model work. In parallel, develop robust, good enough representations for higher level simulations that are tuned by more detailed examinations.

Develop theories of complex systems management and control.

It is important that we not only develop these theories but we must also be able to translate them into practical use. Perhaps there are lessons to be learned here from the civilian communities or international communities.

Develop measurable combat requirements, objectives, and tasks to permit the tradeoff analyses of C^3I and combat systems.

Explore potential role of evolving synthetic environments on C^3I analyses.

Make the workshop results and DIS symposium report widely and quickly available.

We need to energize the entire OR community to tackle this problem and make them aware of the progress that has been achieved so far. We need to include a clear and concise description of Louisiana Maneuvers and its role in this effort.

Enhance the exchange of information on prospects and work in progress on C^2 evaluation.

Focus forthcoming MORS working groups on the key issue of representation of C^2 in analysis.

6.2 Summary

The challenge in working with C^3IEW MOEs is to overcome not only the curse of dimensionality but also the curse of ambiguity. Care must be taken to interpret analysis results to ensure that they are telling us what we think they are telling us.

The workshop renewed an interest in the problems and issues related to C^3IEW MOEs. The challenge for the community is to continue where this workshop ended and maintain the interest that was demonstrated throughout the workshop. We, in separate services and separate communities, must work closer together to maintain a common language, to mutually support one another, and to share our knowledge and experience to improve our capabilities to support C^3IEW systems development, testing, and training.

The results of the Workshop has inspired at least one participant. Mike Sovereign has suggested that NPS host a follow-on workshop to further develop the joint effort initiated here.

Appendix A

Excerpts from Workshop Dinner Speech

COL James McDonough
Director, School of Advanced Military Studies
US Army Command and General Staff College

. . . My topic tonight is What is a Campaign? That is a rather imposing subject. On the one hand, it is a formidable challenge to speak to all of you ORSA experts in what should otherwise be a light and easy-going after dinner speech. . . . On the other hand, it is intriguing to talk to you about my topic, what is a campaign. . . . My approach will be to talk about where we in the Army are going with our doctrine.

My credentials for doing this are twofold. Number one is that I am located at SAMS (School of Advanced Military Studies) and number two, I had some responsibility in preparing the next version of FM 100-5, Operations, the Army's keystone doctrine. . . .

. . . I want to relate doctrine to ORSA because that is what you do and that is the task before us. From whence does our doctrine come? That is the beginning of my talk tonight. How do you take all that you know, all that you have learned in life and bring it all together to write a doctrine for warfare in the 21st century. What follows, then, as a preface to the doctrine is the intellectual odyssey that gets you there.

Let me begin with my own beginnings in this process. . . . To me the big event in my young life, the recent event, was World War II. It was my focus of warriorship as a young man. My father was a veteran of World War II. . . . I admired him, wanted to be like him. And I watched all the great Hollywood war movies — *A Walk in the Sun,* a gripping display of infantry soldiers fighting in Italy; *Twelve O'clock High,* the application of airpower to warfare and the brave men that fought the Battle of Britain and took the campaign to the Germans, *Run Silent, Run Deep,* the thrilling undersea battle taking the fight to the Japanese. From all those reflections, I drew this idea of heroes. We won our war because we had heroes. . . .

When I became a little bit more mature, I began to understand that leadership had some manifestation on how to use those heroes. The great names of my era started to become known to me: Dwight D. Eisenhower, President of the United States, Supreme Allied Commander, five star general; George C. Marshall of the Marshall Plan, architect of the war who would later become Secretary of State and Secretary of Defense. Vinegar Joe Stilwell walking his way out of Burma and telling the press we took a licking, we have got to figure out what went wrong and go back and return the favor — and we did. Omar Bradley, the soldier's general; Hap Arnold, founder of the Air Force; and Bull Halsey, terror of the Japanese, Chester W. Nimitz rises to the occasion, wins our great sea battle during the dark days of 1942, when our seapower seems to have been destroyed; Douglas

MacArthur, a man of vision and a perennial general. The thought entered my mind we won because we had the right leaders not just heroes and soldiers.

A short time later, somewhere in there, I remember reading a story about a baseball team at Fort Benning in the early 1930s. The composition of that team was remarkable. There was George C. Marshall in the stands, Patch in left field, Gerow at short stop, Bradley coaching, Devers at first base and on and on it went. On that team of nine players practically every one of them rose to a three or four star general before World War II was over. The thought occurred to me that it is not just soldiers and leaders, but that it was the richness of our nation in materiel and human resources that brought us victory. . . .

A little later in life, my youth behind me, I went to MIT. I began to run into some of the defense intellectuals of the day. They had a different way of looking at it. Some of you can, I am sure, identify with them. You are contemporaries and protégés of them. George Rathgens who argued adamantly that an air defense system, the ABM system, would not be at all effective in defending the United States against a strategic nuclear attack. He was opposed just as adamantly and just as convincingly by Albert Wohlstetter and the difference between them was really an assumption of the probability of launch and successful separation of the warhead from the booster rocket. The difference between their original assumptions was only 0.2 as I recall it, but it made all the difference in the world at the far end as to whether or not the US could successfully be defended by a missile system.

William Kaufmann, one of the original whiz kids" one of the first at RAND (and RAND is here tonight), taught me the business of quantifying military resources and calculating their military effects against likely opponents. His studies of conventional and nuclear warfare were very quantified, very deep, very provocative. These men, and others like them, were saying there are ways to think about all this, that if you study the piece-parts that can be applied, they will tell you how to put together the best program, the best expenditure package, the best technology to ensure victory as was planned. The scientists, the nuclear theorists, the systems analysts were all suggesting a method of determining How Much Is Enough in military preparedness.

Herman Kahn, Charlie Hatch, Alain Enthoven led me to a study of Robert McNamara and his roots in World War II, how he applies his Harvard-learned skills of systems analysis to the 8th Air Force in Europe and later on to the 20th Air Force in the Pacific, then on to the Ford Motor Company. He rises to be the Secretary of Defense and he institutes the PPBS system by which we fight the war in Vietnam and structure much of our defense business after the war, a system based on the belief that you can look with precision and find the critical node, analyze it, vary it and measure the outcomes. P. M. S. Blackett is his intellectual godfather whose classic studies of war talks about the relationships between tactics and strategy and uses as the basis for his ideas the measurement of the effectiveness of air and anti-submarine warfare in World War II, and how best to apply the resources of war. My store of information on warfare was now starting to get quite large and unwieldy, indeed.

Finally, in my thinking I show up at SAMS, encouraged to do so by the prescient Huba Wass de Czege. He, as you know, was so instrumental in the rediscovery of operational art and the convincing of our the Army that we needed to work on that. From him and through SAMS, I begin the studies of theories of war that run the gamut from Clausewitz, Jomini, Sun Tzu, Mahan, Douhet, Liddell Hart and Van Creveld, and the Russians Svechin and Tukhachevsky. At this point, one starts to come to grips with the reality that war is a very complex business, that after all the study of war is just a jumble, just like war itself; but out of it must come order. You have to study the parts but integrate it into the whole.

When we took upon ourselves the task of writing the Army's doctrine we understood from the get-go that forecasting the way of war was the most difficult thing in front of us, that whatever doctrine we devised would live in a sea of uncertainty — the uncertainty of whether or not we had it right, and that a wrong guess could result in calamity.

Michael Howard at Yale advises — and we took his words to heart — that the best you can hope for is not to have it so terribly wrong that you lose at the onset of the first battle. That's not a very optimistic view point. As we began the process of redoing our doctrine, we hoped to do better. Whether we did or not remains to be seen.

My message tonight as I take you into the business of doctrine is threefold: the first thing is to recognize that warfare — understanding it, planning it out and fighting it victoriously — is both an art and a science; the second thing is that we chose to describe how we as an Army thought about war, not prescribe how we expected everyone to fight it in detail; the third is that your particular skills of operations research and systems analysis can help in improving our application of the tools of war in specific instances, but that even then it remains an uncertain business, affected by the so many intangibles the Clausewitz defined as fog and friction and chance.

. . . What are the major points of our operational doctrine? What follows is just really a surface treatment of the major issues.

The first thing is the idea of the compression of the strategic, operational and tactical. Although there are different levels of war, the line between them are fine and not all that clear. Any commander must realize that he transgresses from one to the other in short order if the conditions are right. This has major ramifications on the way we fight. Second, we need to define the end state at the beginning — not at the end. You need to know where you are going before you start. Third, from that, comes the understanding that the campaign doesn't end with the last shot. You begin a campaign in order to accomplish strategic ends. Often those strategic ends are not really anchored until you put into effect operations that will continue after the end of war. Fourth, you can not assume yourself at the point of the struggle — the locale of the campaign — at the start. That was a convenience of our doctrine during the Cold War. We assumed ourselves present. We would fight the war in Europe and we were there in force at the start. Forward defenses was our strategy, it was our watch word. We had over 300,000 Americans in uniform in Europe, even before any fighting began, matched by up to 60 days of supply. Force projection is the watch word now and with

it a number of difficult tasks. We will have to get ourselves to the contested region, along with virtually all our supplies. That will be a difficult and challenging business. I think ORSA could very definitely apply itself there. How do you get there, when, in what order, and for what effect.

That leads quite directly to the next concern, integration of all types of war into a keystone doctrine. Not just a conventional war, but all kinds of war: the conventional, the unconventional, the nuclear, weapons of mass casualties — all of these can coexist simultaneously in the same theater of operations. One can flow into the other and they must all be addressed in a holistic manner. That should be done in our keystone doctrine.

We take into account that not all we do is warfighting, that we, the Army, often find ourselves in operations other than war. These operations are not unimportant. They do not degrade our central focus on warfighting. In fact, they are related to virtually any campaign you can concoct. But they are also important in and of themselves. They must be understood and the doctrine must be there to help us think about it.

In one of our most central concerns — and I think innovative thoughts — for devising doctrine, we came to terms with understanding that there is an American way of war, one that is uniquely American, and that, therefore, both constrains us and brings us the opportunity to think about war in certain ways. For example, one outcome of that is the desire to achieve quick, decisive victory with minimal casualties.

We related this idea of an American way of war to a world of tighter communications, a shrinking globe where CNN was ever present. We must imbed in the mind of the commander that once he initiates his operations, the sands of time are running through the hourglass; he is being observed, in ways that are unknown to him. Whatever action he takes will have political, and therefore strategic, consequences in the homes of the voting public. Consequently, it will have an impact on the conduct of our campaign.

We entered into at least the first draft with the idea of versatility as a tenet, adding to the original four of initiative, agility, depth, and synchronization. It was not enough to be agile, to shift within the theater of operations from one mode of fighting to the other. We also had to be able to shift quickly between theaters and between types of warfare and from warfare to operations other than war. We recognized that we needed to do all this all with a shrinking base, that it had to be done professionally and proficiently, without ever losing stride. We also attempted to articulate a concept we call battle space. Battle space, yet to be finely resolved, deals with both the intellectual concept and the physical space in which the commander fights his fight. We have likened it to the ring mastery of the masterful boxer who knows within the confines of his ring -- his battle space — he must operate by using every available asset. He must decide when to strike, when to maneuver, when to attack, when to defend, and when to put in the finishing blow.

We also tried to come to grips with the multi-dimensionality of war. We no longer call it just AirLand Battle; in fact that term has faded. We have not walked away from airland battle but we recognize warfare as something a lot bigger than that. It is

air-land-sea; it is space; it is special operations; it is electromagnetic; it is joint and combined; it is multi-dimensional war and it must all be brought together into one whole.

Tempo enters into the con of our doctrine and what we mean by it, which is not just speed. There are times when you speed up and you quicken the tempo; there are times when you slow down and you back off the tempo. Certainly it is a measure in the effectiveness of war and has central importance to successful warfighting. We took an old concept — deep, close and rear battle — and we really thought about that. We redefined its purpose. We used to say that deep battle was germane only so far as its effectiveness to close battle. Today we believe that is not the sole determiner. Deep battle must also be related to its effect on future battles. The simultaneity of operations throughout the depth of the battle became a more powerful concept. It is geared not only to close battle but to future events as well that determine the outcome of the campaign.

Finally, in this short list of major points of what we did with our doctrine we tried to relate technology to doctrine. Although we did not use words as high-falutin as this, the idea we applied is that there is a symbiotic relationship — one affected the other — and they had to come together in a sensible way. You just do not reach for whatever technology that happens to be out there and overlay that existing doctrine. You just do not readjust the doctrine every time a new item comes down the pike. Both had to adapt to the other and from that integrate the relationship between technology and doctrine.

Appendix B

Excerpts from Keynote Address

LTG Wilson A. Shoffner
Commanding General, Combined Arms Command
US Army Training and Doctrine Command

Our Army faces many challenges as we respond to a rapidly changing world. Perhaps our greatest challenge is command and control and tactical decision making. My purpose today is to address these two very important topics so you will understand where our Army is going, with respect to doctrine, and what you can do to better prepare our trained and ready Army.

As we work together to meet these challenges, it is helpful to understand how future battle dynamics — how soldiers fight on the battlefield — reveal our requirements for modernizing the force. The battlefield has always been complicated. The future battlefield will continue to be complex.

Battlefield tempo is accelerating. Systems are more lethal, tactical mobility is increasing, range of fires is increasing and more information and intelligence systems are available. Together, this rapid pace will make battles short and violent. Increased tempo on a complex and lethal battlefield has several implications for decision makers. Information may be ambiguous. For sure, decisionmaking will have less time for decisions that will have significant consequences. This battlefield will require agile leaders.

The future requires agile leaders capable of acting faster than the enemy — mentally and physically. Leaders must be capable of rapidly formulating concepts, planning operations, making decisions and pressing the fight. Agile leaders who quickly and accurately apply the conditions of their environment will produce decisive victories.

Command and control procedures must support the agile leaders on tomorrow's battlefield. We must be capable of providing the enemy at least three ways to die simultaneously. That means effectively synchronizing our forces and placing decisive combat power at the right place and time. This requires simple procedures, unified concepts, nested intents, commanders who can see and understand the battlefield, and commanders capable of concurrently considering current and future operations. Calm, competent, confident commanders capable of bringing order to chaos must understand command and control.

The acronym "C^2" seems to suggest that command and control is one word. Command and control is not one word. Each is different and carries with it significantly different responsibilities.

Command is an art. Commanders formulate concepts, visualize a future state, assign missions, allocate resources for those missions, assess risk and make decisions. During the fight, commanders see and understand the battlefield, go to the right place at

the right time, assess the outcome, and anticipate change. Commanders lead, guide and motivate. Command is commander's business.

Control on the other hand, regulates the functions of the organization and is a science. Control is a more precise means through which staffs support their commander's intent and work with other staffs. Control defines limits, computes, monitors, measures, reports, identifies variance and analyzes. This is staff's business. Commanders anticipate change, and staffs project change.

While command focuses the organization, control regulates the functions of the organization. Command cuts across the functional areas at any given echelon. This enables the commander to use his intent and concept of operations to focus the unit and synchronize the battlefield operating systems. Control, on the other hand, operates within a functional area and operates similar to a guild. Control depends upon data and information flow up and down the functional area in a manner similar to a stovepipe. This information flow is necessary, but remember the more control the less command. Our command and control process requires commanders to balance command and control and execute mission type orders.

This process is significantly different from the Soviet troop control model. This critical path methodology is normative, predictive, rational, and easy to automate. However, can we model an intuitive, creative, parallel and sequential process where leaders are able to act in the absence of orders?

Our decisionmaking process is a continuous, intuitive, creative, parallel and sequential process — not an event. All military operations can be divided into three phases. concept formulation, planning, and execution — CPE. Planning and decisionmaking procedures during a campaign differ from those procedures used before a campaign. During battle, leaders need a streamlined process to effectively make decisions in a time constrained environment. CPE is the three phased continuous process that helps commanders during battle.

Embedded in the CPE process is the leader's requirement to continuously build, adjust and execute plans. While building plans leaders need information that supports METT-T [Mission, Enemy, Terrain, Troops available-Time] analysis and concept formulation. Similarly, during plan adjustment and execution, information to leaders must adequately represent the situation — reality. Additionally, leader's reconnaissance must provide information that helps leaders make adjustments prior to and during execution. During each of these phases, leaders need about right information in certain areas to assist with timely, right decisions.

Commanders make different types of decisions. Commanders determine what to allocate, when and where to commit, and what, when, and where to engage forces. These decisions also differ based on the level of war. Tactical decisions are mostly decisions to commit, execute and engage. These are means, space, and time decisions.

Commanders have many challenges with respect to ACE. In this example, the commander strives to minimize the delta between committed and engaged forces. The challenge is to know when to maximize the use of force to get overwhelming combat

power into the fight and change the slope of the line. The commander needs the right information to help make these decisions.

Decisionmaking requires relevant, timely, and accurate information. Not only do we need to know what information is required, but we must also know where that required information will come from. That's only one piece of the equation. We then need to know how to translate this information into decisions, orders and actions. Commanders can't wait for perfect information before making a decision. Even with timely, relevant, and accurate information, the probability of making the right decision is still not guaranteed. Decisions must be decisive and based on about right information. Also, watch out for the somatotropin impact. You know, that hormone which affects your short term memory.

Sleep impacts on decisionmaking. Studies have shown that without sleep, task performance degrades over time. This is not a surprise, but organizing leaders and staff to maximize task performance and instituting sleep plans is key. The conceptual skills required by commanders and like thinking battle staffs to generate concepts are the first skills to degrade. Leaders need rest too. We also must ensure that the right people, type and quantity, are in the right jobs.

The commander has many thoughts but the bottom line for success depends on his ability to make vital decisions. These decisions must not only be based on about right information, but must clearly define what information the commander needs, the availability of good information, and a means of providing the necessary information. Increase the probability of success by using redundant, independent, multiple phenomenology systems that are controlled and available.

Commanders require information to support decisionmaking during tactical operations. Forces accomplish tactical operations through moving, setting, striking, and recocking. Depressing the probability of failure during each of these phases, increases the probability of success. By identifying those events which will cause failure, and identifying the information required to reduce the risk of failure, we focus on what's required to minimize the chance of failure.

While trying to make timely, accurate decisions on the current tactical operation, the commander is also faced with the responsibility of concurrently considering possible future operations. His view is influenced by his assessment of the probable outcome of the current operation. Additionally, the commander must apply information to his estimate of how to best accomplish future operations. Information must support this requirement to continuously consider current and future operations.

Information collection is a complex process. First, consider all the assets available to collect. Then look at all the nodes the information must successfully negotiate. Additionally, the information must get to the right person. Given all this occurs, the information must still be timely, relevant and accurate.

Let's look at collection requirements and consider all the conditional probabilities. All of the events listed by the sensor and the observable event must occur in order to simply say that the sensor is capable of detecting salient targets. That's a lot of if,

and if statements and as you know the probability goes down as we work through an event. There will be holes in the coverage. Holes caused by the sensor and holes created by the event — holes due to masking, field of view, resolution or swath coverage. HUMINT, in may cases, is the only way to fill these Swiss cheese holes.

Assuming collection is possible, this is only one small piece of the kill equation. Again, decisions are required based on the information provided. Information that supports the decide, detect, and deliver methodology will improve decisionmaking.

What was once a luxury if you had the information is now a necessity to successful combat operations. Commanders must know what occurred over the next hill — they must know the outcome of a particular attack. BDA helps commanders allocate means, commit collection assets and execute collection plans. These decisions require timely, accurate, and continuous BDA.

Tempo, complexity, and lethality will all increase on the future battlefield. We have less time to make decisions, and because the battlefield is more lethal, our decisions have a greater consequence. The need for information to support timely and accurate decisions will continue. This is best supported by not continuing to try to model our intuitive decisionmaking process, but by using expert systems with human interface. Work the total system, be ready to fight blind, focus on timely, accurate, relevant information, and increase the chance of making right decisions.

Appendix C

Excerpts from Objective 2 Plenary Address

Dr. Michael G. Sovereign
Naval Postgraduate School

The purpose of this presentation is to provide a quick review for you of the attempts to deal with the problem of identifying C3I measures of effectiveness. The methodology that was developed is called the Modular Command and Control Evaluation Structure (MCES). These efforts are certainly not the only efforts that have been made in the past, but they do have a MORS background and will hopefully get you started thinking along this line. . . .

I am also going to illustrate the procedure through an example of a system which I happen to be working on right now. It is the Vertical Take-off and Landing Unmanned Aerial Vehicle (VTOL-UAV). You will see right away that it is not at the force-level, but rather at the system-level, which is more in line with our effort from the previous MORS workshop. From this work I will try to suggest lessons learned for further methodological exploration. . . .

MCES is a seven module process. The first module is Problem Formulation. In this module the analyst characterizes the decision need, what decisions are being supported, what analysis is required, what assumptions about the problem are required, and what is the mission of the system being investigated. The scenario in which the analysis will be conducted must also be identified here. . . .

The second module is the C^2 system bounding. In this module, we identify the relevant entities, both physical and structural, and the boundaries associated with the system description. These boundaries include subsystem descriptions, the C^2 system, our own forces as well as enemy forces that might interact with the system. . . .

The third module is the C^2 system definition. This will include defining the processes that fulfill the mission. In this module we will also map processes to the system configuration. For the VTOL-UAV, the processes include sensing, assessing, generating the approaches to identify, evade, or trail an enemy, selecting mission priorities, planning; and directing. . . .

The fourth module integrates the statics and dynamics of the system elements with the functions. In this module, we also develop the relationships between physical entities, structures, and processes. This will provide a detailed modeling of the input/output coupling between functions. The results of this effort will be an architecture in which the system functions. This integration of statics and dynamics can be described in terms of entities, structure, and dynamics at various levels. For the UAV example, it would like look this:

Integration of Statics and Dynamics

Level	Entities	Structure	Dynamics
Element	Sensor	Search Pattern	Sense
Subsystem	Payload	Surveillance & Mission Plans	Assess Plan
System	UAV & Mission Plan Center	CIC & NTDs OPGENS	Assess Generate Select, Plan Direct
Architecture	Task Force	ASUW Command Doctrine & OP Order	Assess Generate Select, Plan Direct

The fifth module specifies the measures. We will try to describe the measures at each of the levels of the onion, from the dimensional parameters, through measures of performance and measures of effectiveness, to measures of force effectiveness. This uses the definitions from the '85-'86 MORS Workshop. The measures that we developed for the VTOL-UAV are:

1. Dimensional Parameters (DP):
   a. Weight, size, power, number of channels
   b. Number of parts, complexity, operational modes

2. Measures of performance (MOP)
   a. Payload, range, endurance, speed, altitude
   b. Probability of detection, sweep width
   c. Pointing accuracy, navigational accuracy
   d. Attrition rate, mission success rate (no failures)
   e. Mission planning time

3. Measures of Effectiveness (MOE)
   a. Sweep rate, detection rate, percent of targets identified
   b. Improvement in situational awareness
   c. Efficiency of targeting
   d. Timeliness of tasking of weapons
   e. Time before enemy detects task force

4. Measures of Force Effectiveness (MOFE)
   a. Task force mission success
   b. Mission completion time
   c. Ordnance expended per target killed, force exchange rate

We can look at these measures in terms of the structure of statics and dynamics.

Specification of Measures

Level	Entities	Structure	Dynamics
Element (DP)	Recognitio Differential	Field of View	False Alarm Rate
Subsystem (MOP)	Pointing Accuracy	Sweep Width	Surveillance Efficiency
System (MOE)	Detection Probability	Situational Awareness	Targeting Timeliness
Architecture (MOFE)	Force Exchange Rate	Task Force Mission Success	Mission Completion Time

The sixth module is data generation. This module identifies the timelines for data generation and how the data will be generated — through an exercise, simulation, experiment, or from subject matter experts. In this part of the analysis process, other factors related to data generation are discussed, such as reproducibility, precision and accuracy, collection process and environmental controls. The problem is creating an experimental design that can deal with scenario dependencies and having a man in the loop that is not unlike his real command situation. . . .

The final module is the aggregation of measures and interpretation. This part of the process is intended to assemble the results and draw conclusions about the data. This should answer the basic question — did the system provide a positive contribution. Some issues that need to be addressed here are the scenario dependence of the results, causality of measures — invalidated chain of events, sufficiency of measures, and independence of trials.

Despite community acceptance of this methodology, MCES has not solved the problem of credible C^3I evaluations. I've come up with several reasons for this, and you might be able to add to the list. First, the MOP, MOE, MOFE structure is hard to explain, even to us analysts, let alone the lay person. Second, our ability to model information flow for decisions is crude and lengthy. We can take an enormous amount of time just deciding what is all the information that is needed to make a credible decision. Third, we have very few credible tools and models for measuring combat MOFEs. Fourth, in general, if C^3 MOPs are doubled in value, the MOEs increase about 50 percent, and MOFEs increase only 1 to 10 percent. That's just the nature of the universe, in my opinion. Military command and control systems are very robust already. Adding a little bit more to them doesn't really win you wars. This kind of result is not looked upon with favor by those selling C^3.

Then how come we did so well with Desert Storm? My fifth point is that trained people under motivating conditions can do wonders even with weak systems. Since we

don't model on-the-job training, we didn't predict this and have a hard time dealing with it. Sixth, command and control will always exist. The question is how much C^4I do we add before it begins to get in the way. Finally, I believe that training and doctrine are the most important parts of C^2. The rate of introduction of C^4I may exceed the adaptability of these two. We need to keep it simple.

If that didn't work after six years, where do we go from here? We should perhaps explore new theories of combat and the supporting processes, i.e., C^3 in combat science, stochastic decision models. We should strengthen our joint efforts such as the National Training Center, National Test Bed, and Defense Modeling and Simulation Office (DMSO). We need to be able to respond to pressure for standardization, verification, and validation procedures from Congress, GAO, and users. We need to explore new computer tools such as object-oriented models, simulation languages with libraries of objects, and menu-driven model building similar to the CAD/CAM process. Finally, we need to develop new models of C^3, perhaps in the form of Petri Nets, conditional possibility, and variable resolution modeling.

Appendix D

Excerpts from Objective 3 Plenary Address

Dr. Hank Dubin
USA Operational Test and Evaluation Command

Looking at C^2 measures of effectiveness from an operational test perspective I will begin by identifying some key words within the context of basic Army definitions. I will follow with some typical measures for command and control and discuss how to teach C^2 which might be a way to get a hand on some measures and close with presenting some challenges and potential problems.

There are three classes of traditional C^2 measures that we are looking at to test the Army Tactical Command and Control System (ATCCS): 1) tracking information or messages that goes around the system which is communications, 2) following the activity that occurs within the command post through the Army Command and Control Evaluation System (ACCES), and 3) observing the outcomes of exercises such as training exercises. . . .

I will now show excerpts of the formal, FM 101-5 definitions with emphasis on the italicized words. **Command and Control** is a *process* where forces are *directed, coordinated*, and *controlled* to accomplish the mission. In **Command** there is *authority* vested in the commander to do *planning* and *directing* of resource. **C^2 Challenges** provides for a *complex* situation which requires a *decisive edge* over an opponent which must be achieved and maintained. The C^2 system must allow for a great *variety* of tasks and missions that the commander must perform that require *integration* of many *complex* systems.

The tasks that are to be accomplished through the system consist of three components: organization, facilities, and processes. **C^2 Organizations** include the *relationships, authority* and *responsibility* of the staff and the *functional grouping* of the staff sections. **C^2 Facilities** require supporting automation and communications systems that are necessary for effective command and control. **C^2 Processes** identify the procedures and techniques used to *find out* what is going on, to *decide* what action to take, to issue *instructions*, and to *supervise* execution. Another key item is to **Get inside the decision cycle of the opponent** so that *faster* and *better* than that of the *enemy* is good. The basis for the ACCES methodology is that of considering the headquarters as an adaptive control system. This provides for directing and monitoring the situation and allows the commander develop alternative or new plans based upon how adaptable the plan is when faced with a new assessment of the situation. **Measures of C^2** are *measured* by the extent to which the commander's *intentions* are *carried out* and the ability to cope *quickly* and *effectively* with changes in the situation.

There are also measures of outcomes that identify successful accomplishment of a specific mission. They indicate observable

conditions that can be compared with and without new capabilities that support a process. The process itself in not needed to be known, only the outcome (i.e.. the number of fire missions accomplished or number of aircraft successfully engaged). Correlation of forces and means which is an old Soviet concept is the "school house" solution. In an exercise situation to identify what is needed to get the resources and capabilities in a certain position and look at your ability to meet the threat. . . .

Then there are some intermediate types of measures that compare to ground truth. It's an assessment to see how well we understand various factors about the friendly forces, the enemy forces, the physical environment, and capabilities. Measures depend on context, most are measures of effectiveness and are scenario driven. Measures of task accomplishment must measure the ability to accomplish the mission. It is one of perception, if the commander thinks its better then they will perform better and it does not matter what the "scientists" say. . . .

The Army Command and Control Evaluation System (ACCES) focused on the performance that can be observed in the command post. It assumed that better plans can be executed with less need for modification and therefore the plans remain in effect throughout their intended life. ACCES includes effectiveness measures as well as measures for accuracy of the estimate of the situation. Some of the measures are:

1. Effectiveness:
   a. Percent of plans remain in force unchanged for the intended period of time
   b. Median time used to complete a control cycle
   c. Percent of control cycles due to major incongruities

2. Monitoring:
   a. Percent of information requirements for which there are data
   b. Percent of units for which the most recent data are within the desired time window

3. Understanding: Percent of briefings understood .

4. Estimating and Planning:
   a. Percent of estimates developed by two or more participants
   b. Median time to issue a directive
   c. Percent of correct predictions

5. Reporting: Percent of information requirements reported

6. Coordinating: Percent of cells in a node holding information aboutcide about specific units

7. Network: Percent of nodes holding information that coincides about specific units

Measures of communications would be tracking messages especially within battlefield functional areas to see if the messages get to the right place at the right time and see if the system has the time. . . .

We teach command and control in a variety of ways. Through institutionalized training at our service schools we use four methods that include texts, lectures, exercises, and tests. With field exercises such as a command post exercise (CPX) we teach how to do things better through practical applica-

tion within a simulated combat situation, then balance it through professional readings and attending professional symposia. We give tests to measure what is taught. What we measure with these tests is the ability to reason, recall facts, understand principles, recognize relevant factors. The assessment of these tests comes from outcomes that are judged with respect to the school house solution. . . .

There are practical exercises designed to test the four phases of the decision making process. The first phase is to analyze the mission. Exercises to identify the purpose of the mission, the essential and implied tasks, and the intent of superiors would be performed. . . .

The second phase is to develop facts and assumptions. Here we must develop terrain and obstacle overlays, identify avenues of approach, and consider weather analysis. We must also develop doctrinal, situational, and decision support templates as well as evaluate the logistic estimate. . . .

The third phase is to develop courses of action. Exercises to establish relative combat power, array forces, and develop a scheme of maneuver will be performed. The courses of action will also identify the C^2 means and maneuver control measures and include an operation overlay with a course of action statement. . . .

The final phase is to decide on a course of action. The exercises for this phase is to war game each alternative course of action. This would include preparing an appropriate plan of action needed to counter any course of action by the enemy. . . .

During the evaluation of these practical exercises we must determine what will be measured. It seems reasonable to measure the plans and orders with respect to conforming to Army standards and quality (consistency, completeness, clarity, and executability) as well as project the battle outcomes. . . .

There are three basic C^2 assumptions: More information is better, Faster information is better, and Greater accuracy of information is better. These assumptions place an enormous burden to identify the resources that are required to accomplish a given level of effectiveness. . . .

In conclusion, I must present some major potential problems that must be faced. What do you do to measure intent if the intent changes? At a high level the intent is more likely to remain constant while at a low level intent changes due to external conditions. Standard operating procedures (SOPs) are personality driven. We must be able to evaluate the techniques, procedures, and equipment that supports the decision making process without evaluating the commander's judgment. Variability due to the human element is great. Observations are made on the smallest organizational unit for which the system that is undergoing test is organic. Testimonials may be biased by experience and background. . . .

Appendix E

Excerpts from Objective 4 Plenary Address

Mr. Edward C. Brady
Strategic Perspectives, Inc.

. . . I would like to offer a few observations about some of the issues you have already discussed.

First, I would like to give a different viewpoint about the statements that we better define requirements, bring users and developers together up front earlier in systems development testing, and problems with the pace of technology, etc. I offer you two observations: one is that the Japanese conceived the idea of the Lexus; designed the car; put together a manufacturing capability; and produced it, tested it, and sold it in four years. Most people think it is a pretty damn good car. There is something wrong with our process when many systems take fifteen years in development. While this is well known, I would argue that not only is concept development as difficult or more difficult, but also it is as lengthy as acquisition development. Thus, our situation is much worse than much debate would make it seem. We spend fifteen years in concept development and we spend fifteen years in acquisition and testing, so it takes us thirty years from when we think we need something to when we begin to field the initial increments of new capabilities. In addition, at least in the C^3I area, we almost never succeed at fielding a whole system other than a simple thing like a message handling switch at once. It is important to recognize that, whether we like it, we are locked into some form of an incremental approach not only because of the way in which the technology develops, but also because it is inherent in the basic idea of command and control and intelligence that we will constantly revise what we want. We forget our own history, I think, and that is why we get locked into some of these problems.

For example, I spent a lot of time four years ago traveling around the world, talking to many CINC staffs, talking to the chief communications people in different services, and the J6/JCS. Everyone of them assured me there was absolutely no tactical military requirement for imagery, NONE — based on military objectives, military strategy, and military desire. Today, the most pressing need in many commander's minds is imagery. They not only want it, they want it real time at tactical maneuver level. . . . This type of sudden change in requirements is the norm. Thus, I don't see how there is any hope at all in the kind of arena we work in of having any rigid, long-term standing requirement for a system — even if we understood militarily what commanders today think they want to do. That is not to say that we shouldn't put effort into defining existing requirements, but rather that we also have to find a method that accommodates fluid requirements, a process that lets us implement them in stages, and field increments quickly. Any approach that doesn't contribute to such an end will not be useful.

As a second example, when I was at The

MITRE Corporation, I managed through the period when we first introduced personal workstations. We went through four generations of workstations in nine years. . . .We started a program that said while we are changing what we are buying, we also will reprioritize who has what.. . . The Commanders in the field will never be satisfied if we don't find a process that works like I have described. They will always want something different than a few years before, they will always say what we are fielding is not what they want. They will always say we are too slow. They will always have test beds off on the side, finding something that uses newer technology than the formal program, and replacing whatever system it is — MCS, ASAS — whatever system we have been developing through a logical process. It is just in the nature of it. It is in the nature of the underlying technologies. . . So, we must find processes which accommodate these inherent dynamics and not sit around and wish they were different.

. . . I would draw your attention to LTG Shoffner's constant references to the acceleration in the pace of battle. What this means in terms of C^3I systems is constantly revised information processing requirements. Every time that we can process information faster, the commanders will want to change how they fight and ask that we find ways to process information even faster. That is the nature of our business. . . . As soon as you start to exploit the benefits of automation, you change the functionality of the process it supports. As soon as you change the function, you see new ways to change the requirement, and you change the way you want to fight. . . . As long as these dynamics are true in command and control, intelligence, and electronic warfare, we have to deal with requirement changes during development of systems. We have to deal with them in parallel with technology changes. We have to have a process that supports both types of change.

I would now like to talk a bit about MOEs. A lot of you know that I was a participant, along with a lot of people in this room, in the work that went on in the early '80s which, in my view, largely culminated in the MORS workshop report that you were given in the read ahead package. . . . This effort baselined most of the extant methodology, a lot of models, surveyed what the community had and didn't have. It made recommendations of what we should do next and began to fund research efforts to push us forward. . . .

. . .The most important features of that period were that there was a known community of interest, there was an interest and desire in funding activities, and some progress was being made. You can argue about whether it was fast or whether it was slow, that is not my point. My point is that those involved had an increasing commonalty of definitions and an increasing consensus of what we had and what we didn't have and an increasing sense of where we were going.

One of the things I read on the plane last night coming here was the paper by Ingram and Short. While that paper has much to commend it, I was struck by what I think was the basic factor of that paper. It went back to several original works and said we needed to take a step forward. The question I put to myself was why are we only taking a step forward seven years later? What have we been doing in between? What has happened to the continuity of effort, the willingness to fund research, and everything else? Based on less than comprehensive observa-

tions, I would answer that we have done some good things in between, but we haven't done enough. We have lost too much of the continuity of effort. This forum is important in the sense that it brings people back to the community and refocuses us on a problem area.

It is particularly apropos to do this in light of the ferment going on amongst the military about how do they want to fight, what kind of systems do they need, even what is their mission. . . . we are seeing a resurgence in intellectual thinking about combat and our national role in it. The pressing need to redefine the role of the military in the post cold war era has produced a great amount of very challenging, exciting, interesting thinking. . . . All this provides our analytical community an opportunity to plug into and take advantage of this ferment, regain our former focus and emphasis on measures of effectiveness; our interest in the theory of command and control and how we can experiment, measure, and modify architectures and systems. . . . This workshop offers us a good opportunity to look at these issues.

. . . Since I recently have been spending a lot of time with the Army and we are at an Army installation, I will use some Army examples to illustrate some thoughts I want to share with you. I don't mean to pick on the Army in any way. . . . At Fort Sill, the Army Science Board meeting I was attending had a briefing on a system called ATACMS, which is a long-range Army missile. It was a very, very nice briefing — excellent graphics, easy to understand, lots of computer icons, lots of color — all used to portray an interesting message. It used all the latest tools in multimedia presentations. It also had good analytical substance to it.

The major thrust was — so what is the case for buying ATACMS? Why should we buy it? Of course, the answer was already known since it is an Army system we long have wanted to buy. It was good advocacy analysis. In the course of the analysis, they did what you all know is the right thing to do — they made extensive use of sensor target coverage footprints and timeline comparisons, which then required them as they looked at system capabilities to look at command and control systems. . . . They used very good measures of performance, measures of effectiveness and, they did good quantification of them with very simple arithmetic.

What I would like to convey to you about this study, however, is that we did the same study fifteen years ago, the exact same conceptual system, exact same sensors, and surprisingly enough reached the same conclusions using the same measures. The people who worked on this study did not know this. My suspicion is . . . that they had about ninety to one hundred twenty days to quickly respond to a higher headquarters' need to do some analysis that shows the utility of ATACMS. They are bright, good people. They did a lot of good things in the study, but they didn't build on anything that had already been done, and they didn't know they were reconfirming things that already had been analyzed. . . .

Another thing that struck me about the read-ahead paper . . . is the call for standardization. I happen to personally be schizophrenic about standardization. I wanted to share this bias with you to help you understand what I am about to say. Standards help us in many, many ways. However, they hinder us in two important ways. First of all, once we have standardized, if

we haven't included everything we need to include in our changing environment, it is very difficult to reach agreement to change the standards — and so the standards become inhibitors once we agree to them. Second, most people who issue a call for standardization, and I may have misunderstood the paper in this sense, seem to be saying that if we could just comprehensively a priori define all the measures we need and standardize them we would not have any more problems. . . . To think that we can do this is a normal, top-down analytical way of looking at things. We need to be working on attempts to do so, but to hold up pragmatic attempts to move forward in a bottom-up way while we are waiting for such efforts to succeed would be a crucial mistake. We need to move in both directions in parallel and accept that we will be doing so forever. There are a lot of good things we can do now with what we do have as measures, what we do have as data, and for what we do need to do daily to support the various decisions for which analysis is used. What we usually fail to do is to build these partial efforts continuously into a framework that lets us get closer to the whole. Instead, we do almost everything incrementally. And, do it discontinuously. We do it without knowledge of what each other is doing. We do not keep integrating and building, and stepping back from our efforts and taking top-down assessments of where we are. Where have we already filled in the blanks? What blanks still exist? What new ones have come along?

This brings the discussion back to two of the themes I wanted to convey to you — the lack of a forum, and the lack of a research thrust to what we are doing. While thinking about this, I was struck by a talk show I saw on TV this morning about the presidential debates. . . . The panel said that the problem with the debates is that the questions weren't draw up really well. They weren't focused enough. . . . They gave too much leeway to the candidates. . . An individual in the audience stood up and said they didn't think that was the problem at all. They thought that the problem was the answers the candidates gave! I think we ought to examine ourselves from that point of view. Are we really, in whatever increment of effort we are doing, defining rigorously what measures we want to use and why; and are they, in fact, applicable to the analysis we are conducting or the test we are doing or whatever decision we are supporting? Are they judiciously chosen? Do we know how to measure them, and if we know how to measure them what data do we need to collect to do that? And, if we are going to collect that kind of data, what instrumentation do we need to collect it? I think we need to look hard at the kind of answers we would be giving to these questions. There is a lot of poor quality work done by us. I don't know the reason for that, other than maybe time and resources, and a failure to use earlier work properly. We have excellent studies and we have very poor studies, and they seem to be done side by side. You can go around the community at any given time and find this. . . . It isn't unique to particular organizations or particular efforts. I think we are not hard enough on ourselves about what are the answers as opposed to what we are missing in the form of questions. We don't hold ourselves responsible enough for making continuous progress in defining measures, using them judiciously, and using them consistently — even if we don't know what they all are, even if we don't have standards for all of them, and even if we don't have all the data we need. Thus, I think, from a ground-up way of

operating — we could make a lot of progress towards what we could define from a top-down need.

I want to talk a little about technologies and tools. . .

I think that the advances we are making in instrumentation are quite phenomenal and are very exciting. We could soon collect rooms and rooms and rooms of data and we may do that. What I am worried about is whether we are going to do that to no end, or whether we know what we are doing. For example, the White Sands Missile Range has done a great job of improving instrumentation over the last five or six years. The Fort Huachuca Electronic Proving Ground is now proceeding pell-mell to implement extensive automated instrumentation for SINCGARS and EPLRS testing — because they were not allowed to pursue their instrumentation plan of ten years ago. So it is often in the case of our business. Not because we do not have smart people. Not because they do not think ahead about what they will need. But, rather because of the way that budgets, approval processes, and everything else works — you sort of get things just in time rather than ahead of time.

When you get instrumentation just in time, then you learn how to use it and define what you want to do at the last minute — thus, we make a lot of mistakes. Again, I think that this is inherent in the nature of things. . . . But it is important to remember that we can also say — How can we build on what we did do? How can we learn from what we have now? How can we do the next test better? How can we take advantage of what the Navy already did, or how can we take advantage of what the Army already did? We can only improve ourselves in this way through some kind of community forum that meets periodically and discusses these things.

There will be a lot of testing going on over the next five or six years even though we are now buying a lot less. Many major C^3I systems are just entering early testing, many will be going through product improvement, many will be candidates for significant technology insertion programs. . . . How are we going to know that changes being proposed for systems will really improve it overall as a system? How do we know, if we don't set up an analytical construct, if we change the communications links to do direct fire with imagery to ATCCMS what the impact is on the rest of the system. We have no practical way to get it all out in the field at once and test it.

This brings me to topics like simulation. Many of you know that I have spent a lot of time over the last four years on interactive simulation concepts. I assume most of you know about a DARPA program that they are trying to get off the ground called Synthetic Battlefield Environment on Demand (SYNBED). This is an effort to network ranges together, generally in the Southwest United States — Nellis, parts of White Sands, maybe Twenty-Nine Palms, a Navy thing yet undefined, and the Army National Training Center. Doing this in a way in which the network would be compatible with the efforts in the Distributed Interactive Simulation area, you would allow a ground commander to have an actual battalion in attack at the NTC and an air commander to have actual aircraft coming in and supporting that battalion with close air support out of Nellis; but also have an overall air commander fighting not only the close air support battle but also fighting a whole air

campaign which is filled in with simulation. Similarly, a ground commander would be not only fighting the battalion in attack, but also fighting a simulated whole division. Also, the simulation forces could be paced by the battalion that is actually on the ground and the aircraft supporting it. In addition, one could include all the forces on the flank, rear areas, logistical supplies, etc.

I wanted to bring this up because, assuming that we are going to succeed at implementing this effort, we will have a great environment rich with C^3, intelligence, and electronic warfare activities and many echelons of command — which we do not normally have at our disposal. We will have an enormous range of opportunity for implementing instrumentation. We can practically put in data collection probes anywhere we like. Much of the activity is simulated, yet, we also will have a lot of humans in the loop. The question to ask ourselves is are we ready to do that? What are we going to do with all that data? And, how will we know what it means?

. . . I think the analysts need to get a conceptual framework for their work in place quickly. We are going to be using many new technologies for a lot of things. We are going to be using these capabilities for training, using them for concept development, using them for system definition, electronic prototyping, to carry out part of the testing. What are we in our analytic community going to do about using all this as an opportunity to collect data, to measure things, to test hypotheses we have about what is better than what, about how we know when we have improved command and control and intelligence?

We now have on the battlefield an enormous number of high speed, high quantity collectors of data — sensors. They are dumping data all over the place. What we are struggling with at this point is to define what pieces of data and information are relevant to whom, and where do we want data dumped when. We have a lot of technology moving into the field very quickly that gives us great flexibility in doing this. We have a lot of technology becoming available that the services will presumably buy for training purposes and testing purposes that will provide us with a lot of data.

We could gain a lot of insight into many issues if we had a broad framework of what it is we want to know, and what it is we want to measure, and what our hypotheses are about those things, and how we can go about collecting the data to prove or disprove those hypotheses, and to quantify those measures. I understand that you have had a briefing on the art of command and the science of control. While I agree with the general thrust of this, I certainly don't conclude that we shouldn't measure the art part of command and control. Our measurements here may be more subjective, they may be more difficult; but it certainly isn't something we should stop doing!

. . .I would like to summarize by emphasizing that my own experience in this community, as a participant in combat operations, as a national level intelligence analyst, and an R&D worker in acquisition, all leads me to the same conclusion. We have a process of funding and tasking that is inherently not desirable from a logical, analytical point of view. We get things at the last minute. We are tasked to do things quickly. We don't get the resources when we ask for them, but rather we get them at the last minute. We also have an environment of

warfighting and technology — both of which rapidly evolve. Yet I believe that we can make lots of progress if we put our minds to it. We can have a forum. We do have some amount of money going into research efforts. We can talk to one another and share important information. We can build on the many things that are happening. By doing more of all of this, I believe we can make a lot of progress.

Appendix F

Planning and Organizing Committee

General Chair:	Mr. Vernon M. Bettencourt, Jr. The MITRE Corporation
Host:	Dr. Robert LaRocque US Army TRADOC Analysis Command
Technical Chair:	Mr. Donald W. Kroening US Army TRADOC Analysis Command
Deputy Chair:	LTC Thomas J. Pawlowski III US Army TRADOC Analysis Command
Members:	Mr. J. Douglas Sizelove Office of Deputy Under Secretary of the Army (OR Dr. Patricia Sanders Office of the Director of Program Analysis and Evaluation, OSD Mr. Theodore T. Bean The MITRE Corporation Col Bruce L. Smith Air Force Studies and Analysis Agency
Site Coordinators:	Mr. Steven B. Schorr US Army TRADOC Analysis Command CPT Peter R. Itao US Army TRADOC Analysis Command
Administrative Coordinators:	Richard I. Wiles Military Operations Research Society Natalie S. Addison Military Operations Research Society

Appendix G

Working Group Chairs, Co-Chairs, and Speakers

Dinner Speaker:	COL James McDonough Director of the School of Advanced Military Studies US Army Command and General Staff College
Keynote Speaker:	LTG Wilson A. Shoffner Commander, US Army Combined Arms Command
Group A - Operations, Plans, and Training	
Chair:	Lt Col Kenneth C. Konwin Air Force Studies and Analysis Agency
Co-Chairs:	Mr. Kenneth W. Bernard US Army Combined Arms Command-Training Lt Col Jon Peters Joint Warfare Center
Group B - Analysis	
Chair:	Dr. Michael G. Sovereign Naval Postgraduate School
Co-Chair:	Mr. Royce Reiss Air Force Studies and Analysis Agency
Speaker:	Dr. Michael G. Sovereign Naval Postgraduate School
Group C - Test & Evaluation	
Chair:	Mr. James B. Duff COMOPTEVFOR
Co-Chairs:	Mr. Robert L. Broderson Battelle Pacific Northwest Laboratory Dr. Wayne R. Knight US Army Operational Test & Evaluation Command
Speaker:	Dr. Henry C. Dubin US Army Operational Test & Evaluation Command

Group D - Research

Chair:	Mr. J. Darrell Morgeson Los Alamos National Laboratory
Co-Chairs:	LTC James E. Armstrong, Jr. US Military Academy Dr. Robert J. Might George Mason University
Speaker:	Mr. Edward C. Brady Strategic Perspectives, Inc.

Appendix H

Workshop Agenda

Tuesday	**20 October**
1630-1800	Registration - Frontier Crossroads Club
1800	Call to Order - Mr. Bettencourt
	MORS Welcome - Mr. Wiles
	Host Welcome - Dr. LaRocque
1830	Dinner - Frontier Crossroads Club
	Guest Speaker: COL McDonough, Director, SAMS
	Topic: What is a Campaign?
Wednesday	**21 October**
0800	Opening Session - CR 6, Bell Hall
	Charge to the Working Groups - Mr. Kroening
0815	Introduction of keynote speaker - Dr. LaRocque
0820	Keynote address - LTG Shoffner
	Topic: The role of force-level command and control in a campaign
0900	Break
0915	Working Session for Objective 1
Flexible	Lunch
1330	Summary by Chair, Working Group A
1345	Comments from the other Chairs
1400	Address on Objective 2 - Dr. Mike Sovereign
1430	Break
1445	Working Session for Objective 2
1800	End of Day 1
Thursday	**22 October**
0800	Summary by Chair, Working Group B
0815	Comments from the other Chairs
0830	Address on Objective 3 - Dr. Hank Dubin
0900	Break
0915	Working Session for Objective 3
Flexible	Lunch
1300	Summary by Chair, Working Group C
1315	Comments from the other Chairs
1330	Address on Objective 4 - Mr. Ed Brady
1400	Break
1415	Working Session for Objective 4
1730	End of Day 2

Friday	**23 October**
0800	Summary by Chair, Working Group D
0815	Comments from the other Chairs
0830	Summary from Synthesis Group Chair
0900	Remarks by Technical Chair
0930	Conclusions
1000	End of Workshop
1015	Executive Session with Working Group Chairs

Appendix I

Participants

Addison, Natalie S.	Military Operations Research Society
Allen, Patrick D.	RAND Corporation
Anderson, Charles	SAIC
Armstrong, James E., Jr.	US Military Academy
Baer, Dennis R.	OPNAV 815
Bean, Theodore T.	The MITRE Corporation
Berenson, Paul J.	TRADOC
Bernard, Kenneth W.	Combined Arms Command-Training
Bettencourt, Vernon M., Jr.	The MITRE Corporation
Brady, Edward C.	Strategic Perspectives, Inc.
Broderson, Robert L.	Battelle Pacific Northwest Lab
Carter, Harvey R.	OSD
Chappel, Oscar A.	Potomac Systems Engineering, Inc
Clark, Lloyd N.	AFSAA/SAS
Davis, David. F.	George Mason University
Dubin, Henry C.	Operational Test & Evaluation Command
Duff, James B.	COMOPTEVFOR
Girard, Paul E.	SAIC
Goldberg, Edwin M.	CECOM
Hager, Ralph S.	Lawrence Livermore National Lab
Hollis, Walter W.	DUSA(OR)
Holt, James T.	OASD (PA&E)
Horner, Mary	TRADOC Analysis Command
Ingram, Michael	TRADOC Analysis Command
Itao, Peter R.	TRADOC Analysis Command
Jennings, Joseph F.	The MITRE Corporation
Kelly, Michael	USA Concepts Analysis Agency
Knight, Wayne R.	USA Operational Test & Evaluation Command
Konwin, Kenneth C.	AFSAA/SAG
Kroening, Donald W.	TRADOC Analysis Command
Kromer, William S.	BDM International
LaRocque, Robert	TRADOC Analysis Command
Martinet, Brian	US Army Command and General Staff College
Mayer, Hugo E.	TRADOC Analysis Command
McDonough, James	USA Command and General Staff College
McGruther, Kenneth	USSPACECOM/J3
Metzger, James J.	OASD(PA&E)
Might, Robert J.	George Mason University
Moore, Jerry L.	Combined Arms Command-Combat Developments

Morgeson, J. Darrell	Los Alamos National Lab
Pawlowski, Thomas J. III	TRADOC Analysis Command
Peters, Jon	JWC
Pittman, James T.	Potomac Systems Engineering, Inc
Quensel, Susan L.	TRADOC Analysis Command
Ralston, Mark H.	AMSAA
Ratzenberger, Annette C.	USA MISMA
Reader, Thomas W.	Army Research Lab
Redwinski, Robert J.	AMSAA
Reiss, Royce H.	AFSAA/SAG
Riddle, Thomas	USACGSC
Roberts, John	The MITRE Corporation
Robinette, Stephen	US Army Command and General Staff College
Sandlin, Alan D.	NCCOSC RDT&E Div
Schorr, Steven B.	TRADOC Analysis Command
Shoffner, Wilson A.	Combined Arms Command
Sizelove, J. Douglas	DUSA(OR)
Sovereign, Michael G.	Naval Postgraduate School
Starr, Stuart H.	The MITRE Corporation
Van Wyk, Carl	NAWC, Aircraft Division Warminster
Visco, Eugene P. FS	US Army MISMA
Vozzo, Peter M.	USA Aviation Center
Westmoreland, Herbert O.	Combined Arms Command-Training
Wetstone, Shawn C.	Institute for Defense Analysis
Wiles, John A.	OUSD(A)/T&E
Wiles, Richard I.	MORS
Youngren, Mark A.	The Joint Staff, J-8

Appendix J

Acronyms

ACCES	Army Command and Control Evaluation System
AES	ATCCS Experimentation Site
ALSP	Aggregate Level Simulation Protocol
ARI	Army Research Institute
ATACMS	Army Tactical Missile System
ATCCS	Army Tactical Command and Control System
BCTP	Battle Command Training Program
BDA	Battlefield Damage Assessment
BFIT	Battle Force In-Port Training
C^2FAM	Command and Control Functional Area Model
C^3IEW	Command, Control, Communications, Intelligence, and Electronic Warfare
CAD	Computer Aided Design
COEA	Cost and Operational Effectiveness Analysis
DMSO	Defense Modeling and Simulation Office
DoD	Department of Defense
EAC	Echelons Above Corps
EEA	Essential Elements of Analysis
EW	Electronic Warfare
HEAT	Headquarters Effectiveness Assessment Tool
MCES	Modular Command and Control Evaluation System
METT-T	Mission, Enemy, Terrain, Troops, and Time
MNS	Mission Need Statement
MOE	Measure of Effectiveness
MOFE	Measure of Force Effectiveness
MOM	Measure of Merit
MOP	Measure of Performance
MORS	Military Operations Research Society
MTM	Model-Test-Model
NTC	National Training Center
OPVIEW	Operational Value of Intelligence and Electronic Warfare
ORD	Operational Requirements Document
PACOM	US Pacific Command
PIR	Priortized Intelligence Requirements
SAMS	School of Advanced Military Studies
SME	Subject Matter Expert
SOP	Standard Operating Procedure
SYNBED	Synthetic Battlefield Environment on Demand
TACFIRE	Tactical Fire Direction System

TCDC	Tactical Commander Development Course
TEMP	Test and Evaluation Master Plan
TOS	Tactical Operations System
TRAC	TRADOC Analysis Command
TRADOC	Training and Doctrine Command (US Army)
USACGSC	US Army Command and General Staff College
UAV	Unmanned Aerial Vehicle
VIC	Vector in Commander
VTOL	Vertical Takeoff and Landing